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Indian Standard

CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART V RECTIFIERS AND THYRATRONS

(First Reprint JANUARY 1990)

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

AMENDMENT NO. 1 JULY 1973
TO
IS : 2597 (Part V)-1971 CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES
PART V RECTIFIERS AND THYRATRONS

Alterations

(*First cover page, pages* 1 *and* 3, *Title*) — Substitute the following for the existing title:

' *Indian Standard*

CODE OF PRACTICE FOR THE USE OF
ELECTRON TUBES

PART V RECTIFIERS AND THYRATRONS'

Substitute 'electron tubes' *for* 'electronic valves' and 'electron tubes and valves' wherever it appears in the standard.

Substitute 'tube' *for* 'valve' wherever it appears in the standard.

(ETDC 39)

Reprography Unit, BIS, New Delhi, India

Indian Standard

CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART V RECTIFIERS AND THYRATRONS

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Indian Standard
CODE OF PRACTICE FOR THE USE OF ELECTRONIC VALVES

PART V RECTIFIERS AND THYRATRONS

0. FOREWORD

0.1 This Indian Standard (Part V) was adopted by the Indian Standards Institution on 21 April 1971, after the draft finalized by the Electron Tubes and Valves Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard deals with the additional aspects that are applicable to rectifiers and thyratrons. The general and other more common aspects have already been dealt in IS : 2597 (Part I)-1964*, which is therefore, a necessary adjunct to this standard.

0.2.1 This standard applies to vacuum diodes, gas or vapour-filled diodes, grid controlled gas-filled rectifiers and thyratrons.

0.3 This standard is intended to give general guidance to the designers of electronic equipment to be supplemented by data sheets from the tube manufacturers so that optimum efficiency, performance, life, etc, can be obtained.

0.4 In preparing this standard, considerable assistance has been derived from B.S. CP 1005 (1962) 'Code of practice for the use of electronic valves', issued by the British Standards Institution.

0.5 This standard is one of a series of Indian Standard codes of practice for the use of electron tubes and valves. A list of standards so far prepared in this series is given below:

IS : 2597 (Part I)-1964 Code of practice for the use of electronic valves: Part I Commercial receiving valves

IS : 2597 (Part II)-1967 Code of practice for the use of electronic valves: Part II Special quality receiving valves

IS : 2597 (Part III)-1969 Code of practice for the use of electronic valves: Part III Transmitting and industrial valves

IS : 2597 (Part IV)-1969 Code of practice for the use of electronic valves: Part IV Cathode-ray tubes

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*Code of practice for the use of electronic valves: Part I Commercial receiving valves.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expresssing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960[*]. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part V) covers additional recommendations required for use of rectifier and thyratron, the general and common aspects having already been covered in IS : 2597 (Part I)-1964[†] (*see* **0.2**).

2. TERMINOLOGY

2.1 For the purpose of this standard, the following definitions shall apply in addition to the relevant terms and definitions contained in IS : 1885 (Part IV/Sec 1)-1965[‡] and IS : 2597 (Part I)-1964[†].

2.1.1 *Rectifier Tube* — An electronic tube designed to rectify alternating current.

2.1.2 *Grid-Controlled Rectifier/Thyratron* — A hot-cathode gas-filled tube in which one or more electrodes initiate, but do not control, the anode current.

3. RATINGS

3.1 Peak Inverse Voltage and Peak Inverse Transient Voltage — The maximum peak inverse anode voltage is the highest instantaneous anode voltage which the valve can withstand repetitively in a direction opposite to that in which it passes current. In the assessment of the maximum peak inverse anode voltage at which a rectifier is operating, due allowance shall be made for the presence of transients. Transients may appear, for example, as mains and switching surges, or as overvoltages produced when, after current conduction, the inverse voltage rises abruptly to a high value, introducing voltage oscillations.

3.1.1 Surges may increase the calculated or measured standing peak inverse voltage sufficiently to cause arc-over with consequent damage to and possibly the destruction of the valve. Generally their value is difficult to calculate and should be ascertained by means of a cathode-ray oscillograph.

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[*] Rules for rounding off numerical values (*revised*).

[†] Code of practice for the use of electronic valves: Part I Commercial receiving valves.

[‡] Electrotechnical vocabulary: Part IV Electron tubes and valves, Section 1 Receiving valves.

3.1.2 The manufacturer should be consulted for the peak permissible inverse anode voltage for non-repetitive surges.

3.2 Critical Grid Voltage — For every value of the anode voltage, there is a definite value of grid voltage at which the pulse will fire. If this firing point is plotted (grid voltage *versus* anode voltage), the firing (control) characteristic is obtained which should be furnished by the manufacturer in order to ensure reliable firing and to avail of the facility of control.

3.3 Peak Anode Current — Adequate precautions should be taken to ensure that the peak anode current does not exceed the manufacturer's rated value. For a condenser input filter, when a minimum value of limiting resistance appears in the published tube data, the figure quoted should be taken as including the resistance component of the source impedance but excluding tube resistance. Any resistance specifically added to make up the necessary minimum may be put either in the primary or in the secondary circuit of the supply transformer. In the former case, however, due allowance shall be made for the transformer ratio. Where it can be shown that other design precautions have been taken to ensure that both the working and surge peak current cannot exceed the permitted maxima, the omission of series limiting resistance may be permissible, but it is recommended that the tube manufacturer be consulted. In gas or vapour-filled tubes the current is limited mainly by the circuit impedance and only to a relatively small extent by the tube itself.

NOTE — Attention is drawn to the provisions of 3.8.1.

3.4 Maximum Surge (Fault) Anode Current — The maximum surge (fault) anode current rating applies to transient conditions only; exceeding this value, even once, may reduce the life of a tube; and repeated surges may destory it. The manufacturer's data may be consulted for designing suitable protective devices for interrupting the surge (fault) current accordingly within the specified time (usually 100 milliseconds).

3.5 Maximum Average Current — This is the maximum average current which the valve is designed to carry continuously. In the case of a continuously repeating cycle, for example at commercial frequencies, the average current may be measured by a dc moving coil instrument under steady load conditions. Otherwise, it is necessary to calculate the average current over a period not exceeding a definite time interval which is usually specified by the manufacturer. When the load fluctuates, the readings should be averaged over the averaging time specified in the tube data.

3.6 Frequency — Attention should be given to the manufacturer's recommendations regarding operating frequency. Except where otherwise stated the ratings apply to operation at commercial frequencies that is 25 to 60 Hz.

3.6.1 The lower the frequency, the longer the time for which it is necessary for the anode current to be continuously at or near its peak value: some manufacturers, therefore, reduce the peak current rating for operation at the lower frequencies. On the other hand, the higher the frequency, the less the time allowed for deionization between successive positive half cycles; this sets an upper limit (which depends on the conditions of service) to the frequency at which controlled operation is possible.

3.7 Commutation Factor — The commutation factor is related to the process of deionization and is governed by external circuitry (*see* **6**). The commutation factor as specified in the tube data shall not be exceeded.

3.7.1 The commutation factor may be measured by means of a dual beam-cathode-ray oscilloscope. From the curves of $i = f(t)$ and $V = f(t)$, the current in amperes is read off 10 microseconds before commutation and the time t_2 (μs) taken by the anode voltage after commutation to reach 200 V in the succeeding inverse phase. Then the commutation factor is $20\, i/t_2$.

3.8 Rectifier Rating Charts — Rectifier ratings for voltage and current are inter-related in such a manner that it is often convenient to express them in the form of three charts generally described as rectifier rating charts. The use of these charts will ensure that a tube will be operated with the maximum possible efficiency without exceeding its published ratings. These charts apply only to single phase configuration. For multiphase configuration, relevant factor should either be calculated or should be ascertained from the manufacturer.

3.8.1 Examples of the rating charts and an explanation of their use in relation to types of filter, supply resistance, output voltage etc, are as follows:

a) *Choke input filter* — The maximum anode supply voltage which may be used as indicated at point *G* on Rating Chart I (Fig. 1). This voltage is the open circuit rms voltage available at the supply terminals.

Satisfactory operation within the published ratings may be achieved at any dc current output within the boundaries *A*, *B*, *C*, *D*, *G*, of rating Chart I, provided that, at all times, the choke input filter inductance is not less than the minimum value necessary for good regulation and smoothing.

Under the limiting conditions represented by point *C* the inductance quoted for the choke input filter will not necessarily provide adequate regulation and smoothing at lower values of dc output current. It is within the scope of the equipment designer to estimate the higher value of choke input filter inductance required.

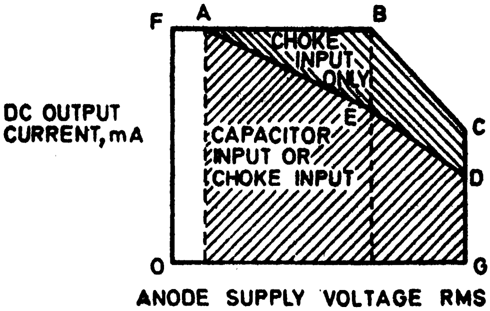

FIG. 1 RATING CHART I

b) *Capacitor input filter* — The range of dc output currents which may be obtained over the permissible range of anode supply voltage is indicated by the boundaries *A*, *E*, *D*, *G*, on Rating Chart I, but reference should be made to Rating Charts II (Fig. 2) and III (Fig. 3) so that operation within the maximum peak steady state, and maximum surge anode current ratings is assured.

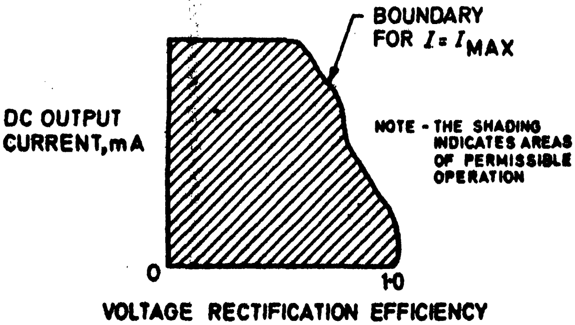

FIG. 2 RATING CHART II

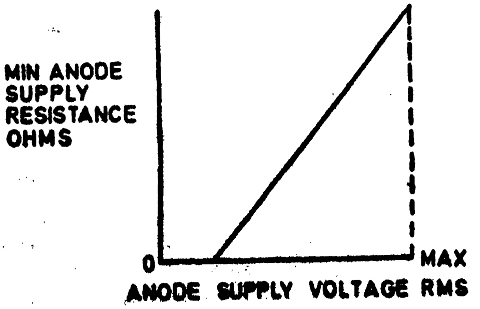

FIG. 3 RATING CHART III

Rating Charts II and III should be used in the following order:

1) *Minimum supply resistance* — For the required anode supply voltage determine from Rating Chart III the minimum supply resistance necessary per anode so that operation within the maximum surge anode current rating is assured.

The minimum value of supply resistance includes the resistance presented by the transformer windings to the anode circuit, and if necessary, additional series resistance shall be added to the anode circuit to obtain the minimum value found from Rating Chart III.

Adequate protection against surge (fault) current is not assured (*see also* **3.4**).

2) *Maximum dc output voltage* — Rating Chart II shows that for a given dc output current there is a maximum value of voltage rectification efficiency or dc output voltage beyond which the maximum peak steady state anode current is exceeded.

The voltage rectification efficiency at the required anode supply voltage and dc output current shall be less than or equal to the voltage rectification efficiency obtained from Rating Chart II for the required dc output current.

If the rectification efficiency exceeds the value obtained from Rating Chart II, additional series resistance shall be added to the anode circuit to reduce the peak steady state anode current to a value less, or equal to the maximum rated value.

The voltage rectification efficiency is found by measurement of the dc output voltage using the following relationship:

$$\text{Voltage rectification efficiency} = \frac{V_o}{E\sqrt{2}}$$

where

V_o = dc output voltage in volts, and

E = anode supply voltage in volts rms.

3.9 Multiple Ratings — Particular emphasis is directed to the warning given in **3.3** of IS : 2597 (Part I)-1964* that voltage and current ratings on rectifiers are not mutually compensating, and where several alternative voltage and current ratings are given, it should not be assumed that these can be safely extended in either direction.

3.10 Input Filter — When the published ratings of a rectifier are stated specifically for a choke-input filter only, it should not be used in a capacitor-input filter except after consultation with the manufacturer.

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*Code of practice for the use of electronic valves : Part I Commercial receiving valves.

4. MOUNTING

4.1 All rectifiers and thyratrons which contain mercury vapour, partially or wholly, should ordinarily be mounted base down and in a vertical position. Care shall be taken while mounting to provide adequate ventilation and proper fixation in the socket. The surface of each of the socket contacts shall always be clean and free from oxidation. Improper contacts lead to increased contact resistance with consequent reduction of voltages in the filament circuit. They produce overheating of the tube due to insufficient emission.

4.2 To prevent damage due to vibration of severity exceeding 0·5 g, spring suspension shall be provided.

4.3 In cases where several tubes are to be mounted, a minimum distance between the tube bulbs should be maintained in order to avoid overheating. It is recommended that this distance should be at least half of the bulb diameter.

4.4 Since external electric and magnetic fields due to metal parts or leads in the vicinity of the bulb may result in back firing inside the tube adequate shielding should be provided. The anode lead should be led away at right angles to the bulb instead of parallel to it.

4.5 The glass bulb and contacts should be cleaned periodically.

5. COOLING

5.1 A gas-filled tube shall be operated within definite temperature limits. If a tube is being operated at high ambient temperatures or at its specified maximum ratings, adequate flow of surrounding air or fan cooling shall be provided. However, care shall be taken that the lower part of the tube, where mercury condenses, shall be maintained at temperature lower than that at the upper part of the tube.

5.2 Envelope Temperature — With a mercury vapour rectifier the vapour pressure is a function of the temperature of the coldest spot inside the valve to which the vapour has unrestricted access. This temperature should be maintained within the limits specified by the manufacturer if use is to be made of the full ratings of the rectifier.

5.2.1 The performance of the mercury vapour rectifier differs from that of the high vacuum rectifier in that, owing to the presence of the mercury vapour, the voltage drop between anode and cathode in the conducting direction is comparatively low and normally of constant value, usually between 6 and 20 V. Although this voltage drop is negligible in comparison with the output voltage of a high voltage rectifier, it is important in the rectifier itself. As the cold spot temperature is reduced, the voltage drop increases and with it the energy dissipated in the tube;

this may lead to overheating and sometimes it causes damage due to excessive ionbombardment of the cathode.

5.2.2 Any increase in a tube drop is likely also to increase the anode dissipation beyond the permitted maximum value, with the possible ill effects of anode emission and cathode poisoning by release of occluded gases.

5.2.3 On the other hand, if the cold spot temperature (and hence the vapour pressure) is allowed to increase, the inverse voltage which the valve can withstand is reduced. This voltage decreases very rapidly as the temperature increases above the maximum permissible rated value.

6. DEIONIZATION TIME AND RECOVERY TIME

6.1 After anode current has ceased to flow, a process of deionization takes place, in which the electrons and ions in the discharge space recombine to form uncharged gas or vapour molecules. The rate of deionization is a function of electrode design, the gas or vapour pressure and the degree of ionization present in the discharge space. The degree of ionization present is itself a function of the anode current and the rate at which the anode current falls to zero.

6.2 Deionization of a given gap in a gas-filled tube is the time required for the gap to regain the preconduction characteristic after interruption of the discharge across the gap. The recovery time of a given gap in a gas-filled tube is the time required for the gap to attain a specified condition (for example, the regaining of grid control) after interruption of the discharge across the gap.

6.3 As the deionization time depends on the grid voltage, two values of deionization time at different grid voltages are given in the tube data. These values are only approximate and they vary with the gas pressure. The specified times are, therefore, approximate values referring to a particular set of conditions and are given mainly for comparison.

6.4 The time required for recovery increases wlth anode current, with the rate at which the anode current falls to zero and with the gas or vapour pressure. In the grid controlled rectifiers and thyratrons, the grid exercises no control during the passage of anode current (except under special conditions not normally met). When current flow ceases, the grid regains control only after sufficient deionization has taken place. The grid voltage required to prevent conduction varies with the degree of deionization and in turn with the anode voltage. The recovery time may be reduced by making the grid voltage more negative or by reducing the grid circuit resistance or by both. A negative voltage on the anode may have the advantage of assisting deionization but it also increases the tendency to flashover with a danger, in extreme cases, of a damage to the tube; it may lead to gas 'clean-up' and reduce the life of valves not provided with auxiliary means of maintaining the required gas or vapour pressure.

7. USE OF RECTIFIERS IN PARALLEL

7.1 When two or more rectifiers are used in parallel, a separate limiting or stabilizing device, such as a resistor or reactor, should be connected in each anode lead. Without these precautions, the rectifier having the lowest voltage drop will carry the heaviest current and may fail because of overloading.

7.2 In gas-filled tubes there is the risk that only one tube may strike and hence it will carry all the current. Thus it is generally undesirable to operate gas-filled tubes in parallel. This restriction does not apply when a second tube is intended as a standby to ensure continuity of service on the failure of the other.

8. TUBE PROTECTION

8.1 Switching On — The filaments/cathodes of gas-filled tubes should be heated for a sufficiently long period before the anode voltage is applied. To allow sufficient preheating, the application of anode voltage should be delayed by a suitable time delay relay. With high voltage rectifiers and thyratrons with (Vinv greater than 5 kV), it is a good practice to raise the anode voltage to its full value in steps or continuously over a period of one to five minutes. Procedures recommended for switching on the tube and applying the anode voltage recommended by the manufacturer should be followed at all particularly with regard to heating time.

8.2 Rapid Start — For applications which require an extremely short preheating time, arrangements should be available to apply a higher filament voltage and for switching on the anode voltage after a specified short heating time. The tube manufacturer should be consulted as regards the value of filament voltage and heating time required in such cases. The higher value of filament voltage is usually obtained by a suitable tap in the filament transformer and the predetermined delay for switching on the anode voltage is controlled by a precise timer.

8.3 Overload Relays — Suitable overload relays shall be provided as protection against excessive load current and excessive peak or average tube current.

8.4 Protective Resistors — In order to limit short-circuit currents resulting from inadvertent short circuits, suitable anode resistors shall be provided.

8.5 Soft Transformer — Use of soft transformers (transformers with large leakage coefficient) is recommended for limiting the back-fire current.

9. RECTIFIERS WITH IONICALLY HEATED CATHODES

9.1 In deciding on the starting supply voltage, due allowance should be made for the fact that the striking voltage of a tube increases with life, otherwise it will be found that the tubes will fail prematurely.

10. CATHODE HEATING

10.1 Provision of Centre Tap — For directly heated tubes where the anode current is appreciable compared with the filament-heating current, it is desirable that the transformer secondary supplying the heater voltage should have a centre tap from which the anode current is drawn.

10.1.1 It should be noted, however, that in the latter case, the anode current, including any surge or fault current, passes through the heater transformer winding. In some tubes requirements are met by the provision of a separate cathode output terminal which is permanently connected to the mid-point of the filament itself.

10.1.2 In large filament type rectifiers the peak anode current is often several amperes. Owing to the inherently low voltage drop of the rectifier, particularly in the case of the gas-filled type, the voltage drop along the filament is comparable with the voltage drop between anode and filament. The provision of a centre tap results in approximately equal distribution of current when the peak current is moderate.

10.2 Phase Relationship — Maximum ratings specified for large directly heated rectifiers are often based on the assumption that the filament transformer is so connected that the anode and the filament voltages are substantially 90° out of phase. In multiphase supply circuit this can readily be ensured, but in single phase circuits the use of some form of phase shifter is desirable.

10.2.1 For large currents the phase relationship becomes important and if the anode and filament are operated in phase, the anode potential is at its maximum when one end of the filament is at positive maximum and the other end at negative maximum. Anode current then tends to be drawn mainly from one end of the filament, causing uneven heating along the filament which may seriously reduce the life of the tube. If, however, the anode voltage and the filament voltage are 90° out of phase the tendency is to equalize the anode current throughout the filament. A phase displacement of 60° or 120° is generally easier to provide and the tube manufacturer should be consulted as to its acceptability.

10.3 Cathode Heating Time— In gas-filled tubes and in some large vacuum tubes it is necessary to allow a time (specified by the manufacturer) for the cathode to reach the operating temperature (*see also* **8.1** and **10.4**).

10.4 Preheating of Mercury Vapour Rectifiers — With a mercury vapour tube it is necessary to ensure that the temperature of the tube is above the minimum specified operating figure (*see* **5.2**). Except in the case of small tube and with normal or low ambient temperature, this will generally require a longer time than that specified for the cathode heating.

10.4.1 For a mercury vapour rectifier extra preheating of the filament or cathode is necessary after transport or handling, or when the tube has been newly installed or has been inactive for a long period. It is essential that a sufficient time should elapse between the switching off the cathode supply and the application of the anode voltage (*see* **8.1**) to allow mercury deposited on the anode or cathode to vapourize.

10.5 Abnormal Voltage Variations — Whereas for most types of tubes abnormally low heater or filament voltages produce a reduction in emission, in the case of thyratrons irregular operation may also result. Serious damage may also occur in large tubes. Use of automatic voltage regulator for filament power supply is recommended.

11. RADIO FREQUENCY EFFECTS

11.1 Gas-filled rectifiers should not be operated in the vicinity of appreciable rf fields since such conditions may cause continuous ionization or faulty control.

11.2 Ionization in a tube may be caused by a surrounding rf field or by the application of rf voltages to the tube through its associated wiring. It may, therefore, be necessary to screen the valve and its leads or to employ appropriate rf filters.

12. INTERFERENCE FORM GAS-FILLED RECTIFIERS

12.1 A gas-filled rectifier can cause rf interference in adjacent circuits. To avoid this, it may be necessary to screen the tube and its leads and also to insert rf filters in the supply leads.

13. GRID-CONTROLLED RECTIFIERS AND THYRATRONS

13.0 Owing to the presence of grid in these types of tubes, the recommendations specified in 13.1 to 13.3 are particularly applicable.

13.1 Grid Resistance — A series grid resistance is required and its valves should lie within the range specified by the tube manufacturer.

13.1.1 If the resistance is too low, the grid current may be excessive and damage may be caused by overheating of the grid with consequent release of gas, or grid emission. Care should be taken to avoid a grid resistance so low that the voltage at the grid during conduction is more positive than −10 V and during the non-conduction period, the voltage at the grid does not become more negative than −500 V.

13.1.2 If the resistance is too high, the grid may lose control owing to the grid potential being reduced by grid current flow through the grid resistance and the recovery time may be unduly increased.

13.1.3 When operating within its rating, a thyratron shows approximately linear relationship between its grid potential and the anode voltage necessary to start ionization. Above a certain anode voltage this linear relationship no longer holds and breakdown may occur even though the grid is highly negative. If a tube is operated in this region it will be unstable in operation and may become completely uncontrollable.

13.2 Automatic Bias — In circuits which apply automatic bias the sum of the bias voltage developed and the peak value of the heater voltage shall not exceed the heater-to-cathode voltage maximum specified by the manufacturer otherwise it may initiate and sustain ionization between heater and cathode, thereby modifying, if not nullifying, the control exercised by the grid.

13.3 Control Characteristic with Directly-Heated Cathode — Attention is drawn to 3.9 of IS : 2597 (Part I)-1964*.

13.4 Gas Reservoir — Some manufacturers provide an extra store of gas inside their thyratrons in addition to the free gas present in the envelope. This gas is absorbed in a reservoir (or replenisher) from which it can be released by suitable local heating to replace gas lost during operation by the gas clean-up. This device lengthens the useful life of such valves and ensures that the optimum gas pressure conditions can be maintained in the tube over most of its extended life.

13.4.1 It is important that the manufacturer's recommendation for the operation of the reservoir or replenisher heater should be followed.

13.5 Switching Speed — Switching speed is the rate at which the thyratron is made to fire after the grid regains its faculty of control. The maximum speed that could be obtained has necessarily to be governed by the recovery time. If the period during which a thyratron is not fired is shorter than the recovery time, the control of the tube is no longer possible.

13.5.1 Operational hints for higher switching speed may be obtained from the manufacturers, if required.

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*Code of practice for the use of electronic valves: Part I Commercial receiving valves

14. STORAGE AND TRANSIT

14.1 Particular care should be taken in the storage of mercury vapour rectifiers. Once a tube has been conditioned, no redistribution of mercury should be allowed to take place. Precautions should be taken so that the tubes are not tilted either in storage or while transferring from circuit to storage or *vice versa*.

14.2 The original crate or packing may be used for storage and for transit.

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†Western	Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95

Branch Offices:

'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	2 63 48 2 63 49
‡Peenya Industrial Area 1st Stage, Bangalore Tumkur Road BANGALORE 560058	38 49 55 38 49 56
Gangotri Complex, 5th Floor, Bhadbhada Road, T. T. Nagar, BHOPAL 462003	6 67 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5, Ward No. 29, R.G. Barua Road, 5th Byelane, GUWAHATI 781003	3 31 77
5-8-56C L. N. Gupta Marg (Nampally Station Road), HYDERABAD 500001	23 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	6 34 71 6 98 32
117/418 B Sarvodaya Nagar, KANPUR 208005	21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
T.C. No. 14/1421, University P.O., Palayam TRIVANDRUM 695035	6 21 04 6 21 17

Inspection Offices (With Sale Point):

Pushpanjali, First Floor, 205-A West High Court Road, Shankar Nagar Square, NAGPUR 440010	2 51 71
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 411005	5 24 35

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*Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072 27 68 00

†Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007 89 65 28

‡Sales Office in Bangalore is at Unity Building, Narasimharaja Square, Bangalore 560002 22 36 71

Reprography Unit, BIS, New Delhi, India